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Est-ce que le régime foncier affecte la phytodiversité et la structure des peuplements des parcs agroforestiers en zone soudanienne du Burkina Faso, Afrique de l'Ouest ?

Does land tenure affect the phytodiversity and stand structure of agroforestry parklands in the Sudanian zone of Burkina Faso, West Africa?

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Résumé

Les problèmes de tenure dans la gestion des ressources naturelles limitent l'adoption à grande échelle les systèmes agroforestiers. Cet article décrit la composition, la structure et la diversité des espèces ligneuses dans les parcs agroforestiers de Tiogo sous deux types de régime foncier. Les caractéristiques écologiques et structurelles des parcelles de végétation ont été calculées pour caractériser la composition des espèces. Diverses mesures de la diversité ont été calculées pour déterminer l'hétérogénéité de chaque type de régime foncier. Au total, 49 espèces ligneuses appartenant à 19 familles et 38 genres ont été identifiées, dont 44 et 48 espèces ont été recensées respectivement dans les champs des non-propriétaires terriens et dans les exploitations des propriétaires. Les familles des Leguminosae, Combretaceae et Anacardiaceae étaient les plus abondantes. Les espèces dominantes dans les parcs agroforestiers étaient *Vitellaria paradoxa*, *Parkia biglobosa*, *Lannea microcarpa*, *Piliostigma reticulatum* et *Piliostigma thonning*ii. Les analyses de variance de l'ensemble de la végétation ligneuse des parcs agroforestiers n'ont révélé aucune différence significative au niveau de tous les indices calculés mais ont montré que les champs des propriétaires terriens étaient les plus diversifiés. La densité des arbres dont le dbh≥5 cm et la surface terrière étaient plus élevées dans les exploitations des propriétaires que dans les exploitations des non-propriétaires. Dans les deux types de régime foncier, les distributions des classes de la hauteur de la végétation ont produit une courbe en forme de J inversé, ce qui confirme que les parcs agroforestiers de Tiogo sont dominés par de jeunes individus. La distribution spatiale des populations des juvéniles était principalement groupée, reflétant la dominance de la propagation clo-

nale. Le défi de maintenir la biodiversité des arbres des parcs en « bon » état doit également tenir compte de la flexibilité du régime foncier et du partage équitable des avantages tirés des arbres.

Mots clés

Biodiversité, Terres agricoles, Régénération naturelle, Richesse et diversité végétales, Écosystèmes semi-arides.

Abstract

Tenure issues in natural resources management limit the adoption of agroforestry systems and effective land use scale. This paper describes the species composition, structure, and diversity of woody species on agroforestry parklands at Tiogo under two types of land tenure. Ecological and structural characteristics of vegetation patches were computed to characterize the species composition. A variety of diversity measures were calculated to determine the heterogeneity for each type of land tenure. A total of 49 woody species belonging to 19 families and 38 genera were identified, of which 44 and 48 species were recorded in non-landowners' farms and landowners' farms, respectively. Leguminosae, Combretaceae and Anacardiaceae were the most abundant families. The dominant species in agroforestry parklands were *Vitellaria paradoxa*, *Parkia biglobosa*, *Lannea microcarpa*, *Piliostigma reticulatum* and *Piliostigma thonningii*. Analyses of variance of the entire woody vegetation of agroforestry parklands revealed no significant differences in terms of all computed indexes but showed that the landowners' farms were the most diverse than non-landowners farms. The density of stems ≥5 cm dbh and the basal area were higher in landowner's farms than in non-landowner's farms. In both types of land tenure, the size class distributions of the vegetation produced a reverse J-shaped curve, supporting that agroforestry parkland in Tiogo is dominated by young individuals. The spatial distribution of the seedling was mainly clumped, reflecting the dominance of clonal propagation. The challenge to maintain parklands' tree biodiversity in "good" condition also needs to consider the flexibility of land tenure and equitability sharing of the benefits from trees.

Keywords

Biodiversity, Farmland, Natural regeneration, Plant richness and diversity, Semi-arid ecosystems

1. Introduction

Land tenure is defined as the legally or customarily relationship among people, as individuals or groups, with respect to land. It is an integral part of social, political, and economic structures regulated by the rules invented by the societies (www.fao.org). Rules of tenure define how property rights to land are allocated within societies (Aeez and Onyem 2013). These rights can also vary over time or space, which have implications on land management, individual/public development initiatives, agricultural production, and food security, especially among agro-based communities (Agrawal and Ostrom 2018). In Sub-Saharan Africa, particularly in Burkina Faso, the farmland is characterized by the cohabitation of trees and annual crops. The integration of trees into farming systems is a traditional land use developed by subsistence farmers to deliver multiple socioeconomic and environmental outcomes (Ndayambaje et al. 2013). Sub -Saharan farmers' association of trees and annual crops has created the concept of parkland systems (Grolleau 1989). The parkland systems are a recognized agroforestry approach that

helps increase productivity and sustain food security while also preserving the biophysical environment (Sanou et al. 2017). Trees on farmlands can serve as a 'saving account', providing for the owners a livelihood safety net, including a buffer against the shocks experienced during periods of food scarcity (Wunder et al. 2016).

Thus, the rights to land and tree tenure are applied to regulate their uses by the non-landowners, especially migrants that are left in the case of Burkina Faso, the north and central regions, characterized by high land degradation and decrease of precipitation, to humid zones (southwest, west, and west-center of the country) in search for agricultural lands and pastures zone (Raebild et al. 2007; Sawadogo 2009). In the latter zones, the immigrants do not have the same rights as the natives to use the land as in their origin villages. Also, indigenous farmers often have more rights to the land they cultivate than immigrants, especially regarding trees.

The immigrants must respect the rules to use natural resources in the host land. The natives define how access is granted to rights to use, control, and transfer land, as well as associated responsibilities and restraints. Usually, it is the chief of land or the landowners who determine the terms of use of lands (who can use what resources for how long, and under what conditions. Thus, the migrants acquire land by loan, gift, and rarely purchase. In these borrowed lands, the owner may reserve the right to exploit tree products, and in many cases, the usufructuary is prohibited from planting trees. Because, in many societies in Africa and Asia, trees are used as a mark of ownership rights (Aeez and Onyem 2013). Tenure issues in natural resources management limit the adoption of agroforestry systems and effective land use scale. The non-landowners have no right to plant trees on the farmland that they exploited for the annual crop production. Also, most of them do not benefit from the economic and other advantages (fruits, wood, fodder, pharmacopeia products) related to trees in the loaned farmlands. Paradoxically, it is rare to observe the landowners' planting trees in the loaned farmlands while the usufructuaries do not have the right to plant. Thus, the residual trees that will exist in these farmlands are the old trees whose capacities to produce seeds for natural regeneration are very low. This situation may be a veritable obstacle in the adoption of agroforestry and the management of tree vegetation on farmland. It could affect the population structure of tree species and diversity on the agroforestry parklands.

This present study examined the influence of land and tree tenure on the agro-phytodiversity of parklands and stands structure. It seeks to point one hand, the importance of maintaining biodiversity and, on the other hand, the contribution of agroforestry parklands in the conservation and maintaining of agro-biodiversity. Based on the findings of this study, suggestions are presented to encourage flexibility of land tenure and tree security and to stimulate the promotion of agroforestry for sustainable livelihood and maintenance of biodiversity.

2. Material and Methods

2.1 Description of the study site

The study was carried out in the four riparian villages near the Tiogo State Forest (12.13'N, 2.42'W), Burkina Faso (Figure 1). The choice of the village was based on the presence of agricultural land use which incorporates trees with crop production. We also took into account the proximity of the village to the Tiogo Forest, where various projects dealing with sustainable forest management have been undertaken along with the promotion of buffer zones agroforestry as a conservation strategy because of the provision of alternative sources of forest products (Sanou et al. 2017). We assumed that the closer a village is to the forest, the greater the interaction between local people and the staff of the State Forest, which has the potential of influencing the decision of the local people in

adopting agroforestry (Ezebilo and Mattsson 2010). The Tiogo State Forest was designated by the French colonial administration in 1940 and covers an area of approximately 30,000 hectares. It is located along the only permanent river in the country (Mouhoun, formerly known as The Black Volta). Phytogeographically, it is situated in the Sudanian regional center of endemism in the transition from the north to the south Sudanian zone (Fontès & Guinko 1995). The Sudanian savanna is an area stretching across the African continent from Senegal in the west to the Ethiopian highlands in the east, which is characterized by a six-to-seven-month dry season and a mean annual rainfall of between 700 and 1200 mm (Breman and Kessler 1995).

The total population of the studied villages is approximately 45,506 (INSD 2007). The main livelihood activities of the residents include extensive livestock grazing and harvesting of various forest products such as fuelwood, thatching materials, poles for construction, and edible and medicinal plants. The main crops grown are *Sorghum bicolor*, *Panicum miliaceum*, *Zea mays*, *Arachis hypogaea*, *Vigna unguiculata*, and *Gossypium hirsutum*. The people mainly engage in subsistence agriculture which is entirely rainfall-fed. On the farms, the farmers retain some trees when clearing land for agriculture. Commonly found tree species include *Adansonia digitata*, *Bombax costatum*, *Detarium microcarpum*, *Eucalyptus camaldulensis*, *Gmelina arborea*, *Lannea microcarpum*, *Mangifera indica*, *Moringa oleifera*, *Parkia biglobosa*, *Sclerocarya birrea*, *Tamarindus indica*, and *Vitellaria paradoxa*.

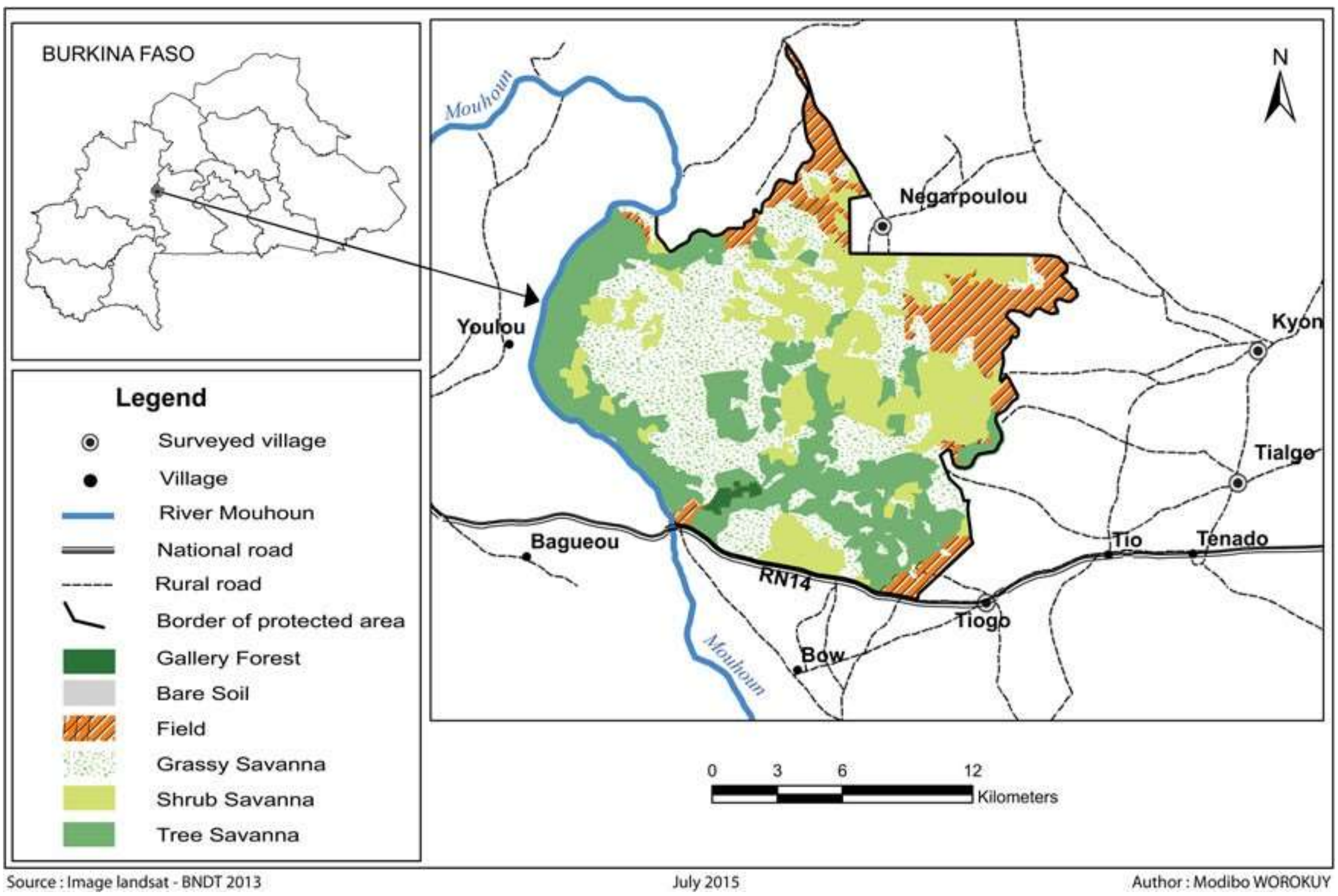


Figure 1: Location of the study site

2.2. Socioeconomic survey and floristic inventories

The findings discussed in this article are a combination of data derived through farmers' interviews and field surveys. Prior to selecting a representative parkland, samples for inventories, focus group discussions, and interviews with key informants were held. The focus group participants and key informants included local chiefs (chiefs of land and chiefs of the villages), government officials of land security, and members of development agencies. The primary aim of the discussions was to determine who could use what resources for how long and under what conditions. Information acquired during different discussions allowed us to identify the landowners and non-landowners. A total of 64 household heads were randomly selected, taking into account their land tenure status (landowners and non-landowners). For the factors of tree conservation on farmland, the interviewees were asked to rate them on a 4-point Likert-type scale (Clason and Dormody 1994) as 1 = not important, 2 = moderately important, 3 = important, 4 = very important. An unbalanced Likert-type scale was used in this study in order to reduce the tendency of interviewees to choose the middle point scale. This is a means of reducing potential biases in the results of this study (Sanou et al. 2017). Interviewee reasons to incorporate and plant trees on their farms took a "yes' and 'no' answer. The farms of 30 natives (landowners) and 34 migrants (non-landowners) were considered inventories. Thus, the structure and tree biodiversity of *Vitellaria paradoxa* parklands that are the most common agroforestry parkland in the study site, were assessed at the household level differentiating between landowners and non-landowners (Augusseau et al. 2006). A total of 64 samples of 50 m×50 m were marked in representative agroforestry parklands. Each plot was then systematically surveyed, and all woody species were marked and identified. The following variables were also recorded: number of stems, the height of the largest stem using a graduated pole, and circumference at 0.2 m and at breast height (1.3 m), using a measuring tape (Savadogo et al. 2007). In this study, we considered mature trees attaining dbh >2.5 cm and height >1.5 m, and seedlings otherwise. All the trees and/or shrubs encountered were identified at species level and nomenclature following Arbonnier (2009) and www.ipni.org.

2.3. Data analysis

Vegetation species composition

The species composition of the plots was described by the following parameters: Relative dominance (RD), Relative density (RDs), Relative frequency (Rf), Relative diversity (RDi), and Importance value index (IVI). Each variable was calculated based on the specific equation mentioned below.

Table 1: Presentation of the formulas

N	Formules	Sources
1	$RDo = \left(\frac{Total\ basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species}\right) x100$	Savadogo et al. 2007
2	$RD = \left(\frac{Number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ individuals}\right) x100$	
3	$RF = \left(\frac{\text{Frequency of a species}}{\text{Sum of all frequencies}}\right) x100$	
4	$Rd = \left(\frac{\text{Number of a species in a family}}{\text{Total number of species}}\right) x100$	

5 $$IVI = \text{relative dominance} + \text{relative density} + \text{relative frequency}$$

Note: RDo=***Relative dominance; RD=Relative density,RF= Relative frequency; Rd= Relative diversity, IVI= Importance value index***

Structure of agroforestry parklands

Structural characteristics (stem density, basal area, diameter, and height class distributions) were computed for each plot and averaged per ownership for all individuals with a dbh≥ 5 cm. The analysis of the diametric structure of the woody vegetation by ownership was carried out through the histograms of relative frequency distribution.

Measurement of diversity

To compare diversity within each type of land use plot, we calculated diverse indices that are widely used for biological diversity measurements (Magurran 2004), such as McIntosh's index, Menhinick's index, Pielou's index of equitability, McIntosch's index, Shannon's measure of evenness, Shannon-Wiener index, and Fisher index of diversity. For β -diversity (similarity between vegetation patches) evaluation, Jaccard's similarity index and Horns' modification of Morisita's index were computed. Jaccard's coefficient of similarity was calculated based on the presence and absence data of the species, while Horn's modification of Morisita's index takes into account species abundance. Both indices potentially vary between 0 and 1, and a value close to 1 indicates greater similarity between patches, and hence low β- diversity (Magurran 2004).

Density and spatial distribution of seedling populations

The spatial distribution patterns of the seedling for each species in the grazing gradients are obtained from the calculation of the standardized Morisita's index (Ip) (Krebs 1999) since it is relatively independent of population density. First, the Morisita's index was computed as:

$$I_d = \frac{n \times \left(\sum x^2 - \sum x\right)}{\left[\left(\sum x\right)^2 - \sum x\right]} \qquad (6)$$

Where n is the sample size, $\sum x$ and $\sum x^2$ are the sums of the quadrat counts, and the sum of the quadrat counts square, respectively.

Then two critical values for the Morisita's index were calculated using the following formulas:

Uniform index (M_u);

$$Mu = (\chi^2_{0,975} - n + \sum xi)/(\sum xi - 1) \qquad (7)$$

Clumped index (M_c);

$$Mc = (\chi^2_{0,025} - n + \sum xi)/(\sum xi - 1) \qquad (8)$$

Where $\chi^2_{0.975}$ and $\chi^2_{0.025}$ are values of chi-squared with (n-1) degrees of freedom that has 97.5% and 2.5% of the area to the right, respectively; x_i = given a set of counts of organisms in a set of quadrats and n = number of quadrats.

Finally, the standardized Morisita's index was calculated using the relevant formula out of the following four:

(i) When $I_d \geq M_c > 1,0$; $I_p = 0,5 + [0,5(I_d - M_c)/(n - M_c)]$ (9)

(ii) When $M_c \geq I_d \geq 1,0$; $I_p = 0,5 (I_d - 1)/(M_u - 1)$ (10)

(iii) When $1,0 > I_d > M_u$; $I_p = -0,5(I_d - 1)/(M_u - 1)$ (11)

(iv) When $1,0 > M_u >_d$; $I_p = -0,5 + [0,5 (I_d - M_u)/M_u]$ (12)

The standardized Morisita's index of dispersion (I_p) ranges between -1 and +1. A value of zero indicates a random dispersion pattern, a value higher than zero indicates a clumped pattern, and a value below zero indicates a uniform pattern.

Statistical analysis

The calculated parameters for the vegetation composition and structure were first subjected to a one-way analysis of variance to test the difference among plots associated with differences in land and tree tenure and type of farm. When a significant difference was detected, a pair-wise comparison was made using Tukey's test at the 5% level of significance. Descriptive statistics were used to analyze the data of the socioeconomic survey. For Likert response scales (four-point scales: 1 = not important, 2 = moderately important, 3 = important, 4 = very important), the values on the Likert type scale were added to obtain 10 and then divided by 4 to get a mean score which is 2.5. Then, any mean score equal to or higher than 2.5 for a question indicated that the respondents perceived the question, while a mean score below 2.5 showed that the question was not perceived. All statistical analyses were performed with R software and SPSS 20 software (SPSS for Windows, Release 2013 Chicago: SPSS Inc.).

3. Results

3.1. Profile of the respondents

Table 1 presents the frequencies of respondents in each class with respect to the socioeconomic and demographic variables. Most of the respondents (84.38%) were men, with 53.13% aged 30-50 years. The respondents were composed of 30 natives and 34 migrants. Up to 37% do not have completed secondary school education. The respondents' major sources of income were agriculture and the selling of NTFPS (56.25%), whereas 43.75% generated their income through other activities. The land for agriculture is mainly acquired by inheritance (46.88%), loan (31.25%), and only a few by gift (21.87%).

Table 1: Profile of the respondents

Variables		**Frequency**	**Percentage (%)**
Gender	Male	54	84.38
	Female	10	15.62
Age	[20-30[	14	21.88
	[30-50[	34	53.13
	>50	16	25.00
Education	Illiterate	9	14.06
	Primary school	24	37.5
	Secondary school	2	3.13
	Adulte education	5	7.81
Residence statut	Native	30	46.88
	Migrant	34	53.12
Source of income	ASP	36	56.25
	AGR	28	43.75
	Inheritance	30	46.88

Acquisition of land	Loan	20	31.25
	Gift	14	21.87
Size of farm (ha)	[1-2]	10	15.63
	[2-4]	35	54.68
	[4-6]	14	21.88
	>6	5	7.81

3.2. Vegetation composition and species diversity in agroforestry parklands

In total, 49 woody species belonging to 19 families and 38 genera were encountered during the inventories at all farms. Land and tree tenure did not influence the composition of woody vegetation in terms of numbers of families, genera, and species or the average dbh of mature trees. For individuals ≥ 5 cm dbh, the number of species was higher in the non-landowners' farms than landowners' farms (Table 2). The species with the highest importance values in the non-landowners' farms were *Vitellaria paradoxa*, *Parkia biglobosa*, *Piliostigma reticulatum*, *Piliostigma thonningii* and *Dicrostachys glomerata*, which together accounted for 192% of the total importance value. *V. paradoxa*, *D. glomerata*, *Lannea microcarpa* and *P. thonningii* were the most abundant species in the landowners' farms (Table 3). In both types of land tenures, Leguminosae, Combretaceae, and Anacardiaceae were taxonomically diverse, and the Leguminosae and Sapotaceae had the highest FIV owing to the high stem density (Table 4). In non-landowners' farms, Leguminosae was the species-rich family (14 species), followed by Combretaceae (6 species) and Anacardiaceae (4 species). Also, Leguminosae (9 species) and Combretaceae (5 species) were the species-rich families in landowners' farms.

Table 2: Summary of the species composition and structural characteristics of trees≥ 5 cm dbh for each type of land tenure in agroforestry parklands of Tiogo, Burkina Faso (mean±SE)

Land tenure	**Non-landowner**	**Landowner**
Sample plots	34	30
Stem density per hectare	141±21a	107±26a
Families (number)	19±1a	16±4a
Genera (number)	32±2a	34±6a
Species (number)	44±1a	48±8a
Average dbh (cm)	26,4±1,60a	29.28±0.18a
Basal area m^2/ha	5,63±0,84a	6.12±1.47a

Means with similar letter doesn't vary significantly (P< 0.05) based on Tukey's HSD test.

Abbreviation: dbh=diameter at breast height

Table 3: The five most abundant species in each type of land tenure in agroforestry parklands according to decreasing order of the importance value index (IVI)

Land tenure	**Species**	**Relative dominance (%)**	**Relative density (%)**	**Relative frequency (%)**	**IVI (%)**
Non-landowner	*Vitellaria paradoxa*	47.93	7.72	4.44	**60.09**
	Parkia biglobosa	31.21	1.27	4.23	36.70
	Piliostigma reticulatum	2.47	6.44	27.55	36.46
	Piliostigma thonningii	2.85	6.86	20.70	30.42
	Dicrostachys glomerata	0.57	20.72	7.04	28.33
	Total	85.03	43.01	63.96	192
	Remains	14.97	56.99	36.04	108
Landowner	*Vitellaria paradoxa*	15.99	5.85	1	42.97
	Dicrostachys glomerata	0.36	25.88	5.2	31.44
	Lannea microcarpa	17.34	5.85	0.46	23.65
	Parkia biglobosa	20.05	0.32	2.40	22.77

Piliostigma thonningii	1.11	14.56	6.40	22.06
Total	54.85	52.46	15.46	142.89
Remains	45.15	47.54	84.54	157.11

IVI: Importance Value Index

Table 4: The four most important families in each type of land tenure in agroforestry parklands according to in decreasing order of family importance value (FIV)

Land tenure	Families	Genera	Species	Density (N/ha)	FIV
Non-land-owner	Leguminosae	7	14	220	67.13
	Sapotaceae	1	1	14	57.97
	Combretaceae	2	6	40	20.02
	Anacardiaceae	2	4	6	16.36
Landowner	Leguminosae	9	9	339	54.54
	Sapotaceae	1	1	27	38.06
	Combretaceae	5	5	57	22.25
	Moraceae	1	1	1	19.37

FIV : Family Importance Value

3.3. Structure of vegetation in agroforestry parklands

A total of 5243 individuals were recorded in all farms, of which 95.27% were individuals with dbh <5cm (considered here as an understory). Excluding these saplings or seedlings, stem density was highest in non-landowner's farms (Table 2). The average diameter and basal area were the highest in the landowner's farms compared with the non-landowner's farms. The diameter class distribution of tress in all farms, indicated that the young individuals dominated woody vegetation in the agroforestry parklands (Figure 2). Most individuals, 68% in the non-landowners' farms and 61% in landowners' farms, were in the two first dbh class. Two individuals of *V. paradoxa* and one individual of *P. biglobosa* in non-landowners' farms and one individual of *Ficus platyphylla* and *P. biglobosa* reached >60 cm dbh. The height class distribution of trees in both the farms showed that most of the individuals had the height range from the top two classes (Figure 2). The species having higher diameters also have the increased height in encountered species.

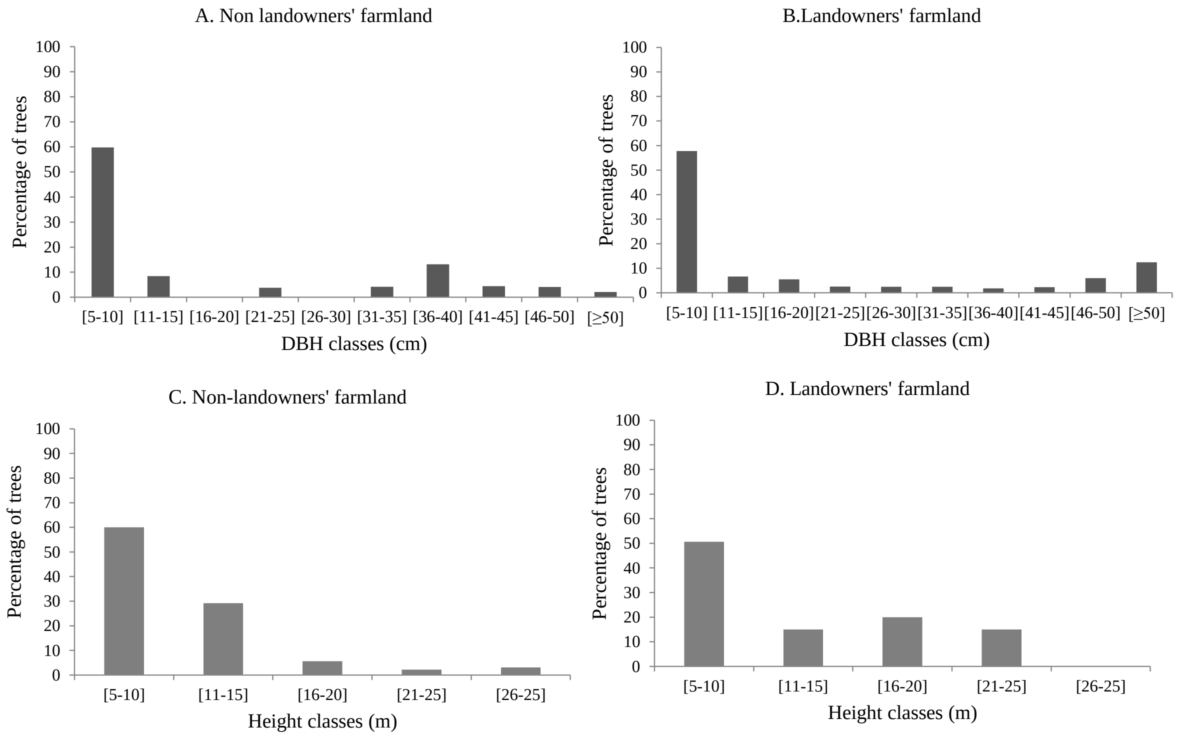


Figure 2: Diameter and height class distribution of individuals ≥ 5 cm dbh in two types of land tenure in agroforestry parklands in Burkina Faso

3.4. Seedling and distribution pattern in agroforestry parklands

The number of recruited seedlings decreased significantly in non-landowner's farms than landowner's farms ($P<0.05$). Woody regeneration was the highest in landowner's farms (197±21 small individuals/ha) than non-landowners farms (89±12 small individuals/ha). Spatial distributions of seedlings of each species at the type of land tenure were obtained from the calculated standardized Morisita's index (Ip), which ranged from -0.5 to 1, showing that certain species had a random dispersion (Ip=0), clumped dispersion (Ip>0) or uniform dispersion (Ip<0). For the non-landowners' farms, all species had Ip values ranged from 0.2 to 1, indicating that these species had a random dispersion. In landowners' farms many species had a clumped dispersion, and few species had a uniform dispersion (*P. biglobosa, Sclerocarya birrea, Terminalia laxiflora* and *V. paradoxa*) and random dispersion (*Gardenia erubescens, Grewia mollis, L. acida, L. microcarpa, L. velutina, Mangifera indica, Pteleopsus suberosa,* and *Tamarindus indica*) (Table 5).

Table 5: Spatial distribution of seedlings population of each type of land tenure in agroforestry parkland

Species	**Type of land tenure**	
	Non-landowner	Landowner
Diospyros mespiliformis	Clumped	Clumped
Detarium microcarpum	Clumped	Clumped
Entada africana		Clumped
Feretia apodanthera	Clumped	Clumped
Gardenia aqualla	Clumped	Random
Gardenia ternifolia	Clumped	Clumped
Gardenia triacantha	-	Clumped

Gardenia erubescens	-	Random
Grewia mollis	Clumped	Random
Guiera senegalensis	Clumped	Clumped
Heeria insignis	-	Random
Holarrhena florinbunda	Clumped	Random
Vitellaria paradoxa	Clumped	Clumped
Lannea acida	-	Random
Lannea microcarpa	Clumped	Random
Lonchocarpus laxiflorus	-	-
Lannea velutina	Clumped	Random
Mangifera indica	-	Random
Mayetenus senegalensis	Clumped	Clumped
Parkia biglobosa	-	Uniform
Piliostigma reticulatum	Clumped	Clumped
Piliostigma thonningii	Clumped	Clumped
Prosopis africana	Clumped	Clumped
Pteleopsus suberosa	Clumped	Random
Pterocarpus erinaceus	Clumped	Clumped
Saba senegalensis	Clumped	Clumped
Sclerocarya birrea	Clumped	Uniform
Securinega virosa	Clumped	Clumped
Sterospermum kunthianum	-	Clumped
Terminalia avicennioides	Clumped	Clumped
Tamarindus indica	Clumped	Random
Terminalia laxiflora	Clumped	Uniform
Terminalia macroptera	Clumped	Clumped
Vitellaria paradoxa	Clumped	Uniform
Ximenia americana	Clumped	Uniform
Ziziphus mucronata	Clumped	Clumped

-signify that the species were not recorded during inventories

3.5. Species diversity in agroforestry parklands

To allow a comparison of diversity between the type of land tenure, several diversity measures were computed (Table 6). The total number of individuals (N) was the highest in the non-landowner's farms than landowners' farms, and it is not the same in richness species. In terms of numerical species richness, defined as the number of species per specified number of individuals (S/N), the landowners' farms had the highest value (0.44).

According to Margalef's index of species richness, representing an intermediate mathematical measure between S/N and S, and Menhinick's index that is a variance of Margalef's index showed that the landowner's farms were the most diverse. According to Pielou's index of equitability, McIntosch's index, and Shannon's measure of evenness, the non-land owners and landowner's farms did not differ significantly and had the same values for these indexes of diversity. The reciprocal of Simpson's concentration index ($1/\lambda$), which specifies the inverse of the probability that any two individuals draw randomly from an infinitely large community belonging to different species would be identical, showed the landowner's farms had the most diverse and the non-landowners farms the least diverse. Fisher's diversity index, the most stringent and widely recommended measure of diversity, also indicated the non-landowner's farms as the most diverse and the landowner's farms as the least diverse. As a whole, most diversity measures showed that the landowners' farms were most diverse than the non-landowners farms. When comparing species similarity between vegetation patches in agroforestry parklands in Tiogo, we

found that landowner's farms and non-landowners farms were more similar (Appendix A). These similarities varied from 61% to 75%, according to Jaccard's index and Morisita's index, respectively,

Table 6: Diversity measure for trees ≥ 5 cm dbh in each type of land tenure in agroforestry parklands of the Sudanian zone, Burkina Faso

Diversity measures	**Type of land tenure**	
	Non-landowner	Landowner
Number of individuals recorded, N,	141±21a	108±26a
Total number of species recorded, S	44±1a	48±8a
Rate of species increase per individual enumerated, S/N	0.31±0.05a	0.44±0.30a
Margalef's index of species richness, D_{Mg}=(S-1)/lnN	8.61±0.40a	9.94±1.14a
Menhinick's index, DMn=S/√N	3.68±0.33a	4.58±0.19a
Pielou's index of equitability, E=H/lnS	0.68±0.07a	0.68±0.03a
McIntosch's index	0.67±0.05a	0.68±0.00a
Shannon's measure of eveness, J'=H'/lnS	0.31±0.03a	0.31±0.01a
Shannon-Wiener index, $H'=-\sum p_i \log_2 p_i$	1.145±0.13a	1.18±0.007a
The reciprocal of Simpson's index, $1/\lambda=\sum n_i (n_i-1)/N_i (N_i-1)$	0.085±0.09a	0.11±0.007a
Fisher index of diversity &= N(1-x)/x, x is the log series parameter	0.76±0.11a	0.58±0.14a

3.6. Main reasons and factors affecting the conservation of trees on farms

The main reasons to incorporate the trees on the farms were more linked to their multipurpose roles (Appendix B). These important roles were food for humans (92%), forage for livestock (85%), soil fertility and protection against diverse forms of erosion (80%), medicine (72%), needs for charcoal and fuelwood (65%), rituals (60%), and absence of certain species in the forest (55%). The respondents did not highly perceive the reasons for shade and biodiversity conservation with a percentage below 50% (Figure 3). Other factors influenced the conservation of trees on farms: lack of funds ($\bar{X}$ =2.97, SD=1.01), lack of skill and silvicultural knowledge ($\bar{X}$ =2.93, SD=0.94), scarcity of land ($\bar{X}$ =2.65, SD=1.03), lack of germplasm ($\bar{X}$ =2.58, SD=0.98) and land and tree tenure ($\bar{X}$ =2.50, SD=0.94) (Table 7).

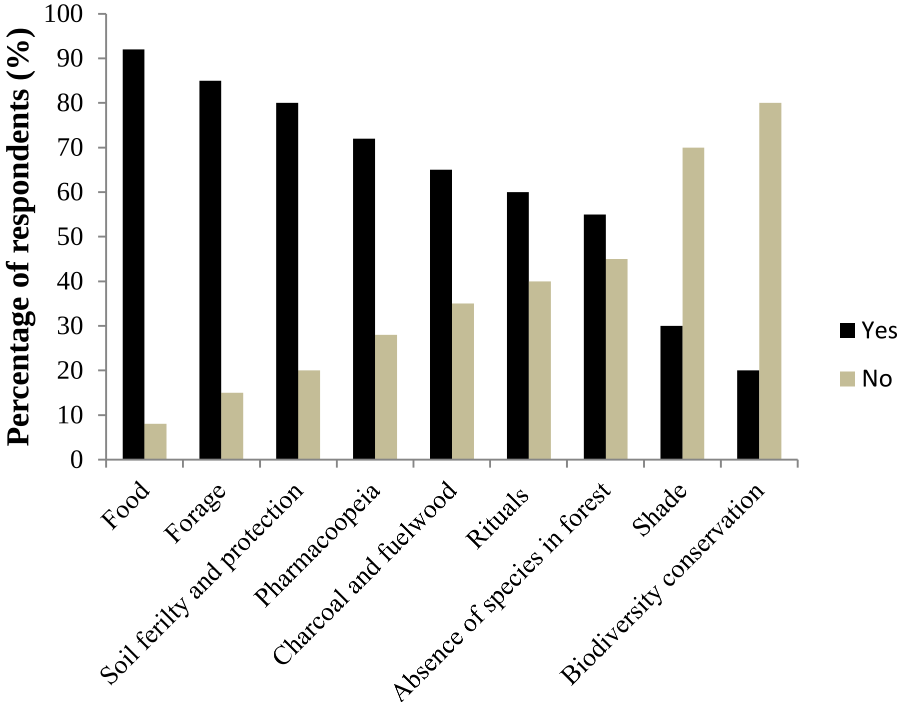


Figure 3: Reasons motivating the conservation of trees on farms

Table 7: Factors influencing plantation and conservation of trees on farms

Factors	Mean($\bar{x}$)	Standard deviation
Lack of fund	2.97*	1.01
Lack of skill and silvicultural knowledges	2.93*	0.94
Land area	2.65*	1.03
Lack of germplasm	2.58*	0.98
Land and tree tenure	2.50*	0.94
Plant diseases and competition to nutrients	2.32	0.85
Culturales and traditional contraints	2.21	1.03

* Significativity

4. Discussion

4.1. Botanical composition of agroforestry parklands

Agroforestry parkland systems maintain a significant level of woody species richness, which may contribute to biodiversity conservation at the national, regional, or even international level (Vodouhê et al. 2011). The numbers of families, genera and species reported in the present study account for nearly one-third of the native woody species found in the savanna woodlands of Burkina Faso. Lebrun (1991) reported that the woody flora (trees, small shrubs, and climbers) at the country level includes 55 families, 214 genera, and 376 species (with 96 exotic species). This relatively high species richness could be attributed to habitat heterogeneity (patchiness), which has increased the tree diversity of woodlands and savannas in Africa (Menaut et al. 1995; Savadogo et al. 2007). Also, the high species richness in agroforestry parklands in Tiogo may be due to perceptions of local communities on the advantages and many economic benefits and opportunities of conservation of trees in farms. The species richness was high in landowners' farms than the non-landowners' farms. According to Vodouhê et al. (2011), the

highest species richness observed in inherited land from their parents (landowners' land) is due to the land tenure system.

The most common families in each type of land tenure were Leguminosae, Sapotaceae, Combretaceae, Anacardiaceae, and Moraceae. According to Fontès and Guinko (1995) and Sawadogo (2009), these families are a pattern common in most savanna-woodland mosaics in Africa and typical of the northern Sudanian Zone in Burkina Faso. The predominance families in traditional agroforestry parkland systems of Benin were Leguminosae and Anacardiaceae (Vodouhê et al. 2011).

The agroforestry parklands are dominated by *Vitellaria paradoxa, Parkia biglobosa, Lannea microcarpa*, *Piliostigma reticulatum, Piliostigma thonningii* and *Dichrostachys glomerata* that are considered as the main multipurpose species used for human food, medicine, forage for livestock, soil fertilization or reclamation, marketable products for rural households. This result is consistent with the findings of Bayala et al. (2008), Vodouhê et al. (2011), and Raebild et al. (2012) in traditional agroforestry parkland systems in West Africa (Burkina Faso and Benin), who found that the most frequent species were *V.paradoxa*, *P. biglobosa* , *L. microcarpa, Adansonia digitata, and Piliostigma* spp. *V. paradoxa, P. biglobosa, L. microcarpa* generated food and the additional income to resource households, especially during the dry season when people are facing food shortage problems. This confirms that agroforestry systems play important roles for household well-being (increase livelihood security, poverty reduction) and incentives forest conservation and sustainable use. This indirectly provides important environmental services such as soil enrichment and erosion prevention, watershed protection, rehabilitation of degraded land, and reducing the environmental risks associated with high climatic variability in the region, carbon sequestration, and opportunities for payments for environmental services, i.e., Reducing Emissions from Deforestation and Forest Degradation (REDD+) program advocated by the United Nations.

In addition, our findings corroborated the previous studies that found that "useful" trees are saved in farmlands for their properties and importance in the daily needs of livelihood (Boffa 2000 ; Augusseau et al. 2006; Jamala et al. 2013). Consequently, the phytodiversity of agroforestry parkland was dominated by these useful tree species (Boffa 1999; Lovett and Haq 2000). From an ecological point of view, the abundance of certain beneficial species is probably due to their adaptability to site conditions and disturbances during labor for annual crops, or the intensification of cultivation maintains ecological niches for the establishment of these species. However, *P. reticulatum* and *P. thonningii*, usually found in fallows with sandy to clay soil, had large numbers of seedlings and adults, supporting the hypothesis of endozoochorus (Razanamandranto *et al*., 2004) or the hydrochorus seed dispersal in savanna woodlands (Savadogo et al. 2007).

4.2. Structure of agroforestry parkland

The stem density per hectare found in the agroforestry parkland in this study was higher compared to the findings of Vodouhê et al. (2011) in traditional parklands of Benin. Also, with regard to stem density, a large number of individuals with dbh< 5 cm corresponding to young individuals (seedling populations) were found in non-landowners' farms and landowners farms, indicating the high regeneration potential of trees. These results are consistent with the findings of Raebild et al. (2007) and Akinbisoye et al. (2014), who reported that borrowed fields contain as many trees as fields cultivated by the landowners and the shrub and sapling densities were significantly high in agroforestry systems. Most woody savanna species regenerate by coppicing and root suckering after disturbances such as fire and wood cutting that frequently occur each year in these ecosystems (Sawadogo et al. 2002). Species such as *Entada africana*, *D.microcarpum, Pteleopsus suberosa* encountered during our inventories

regenerate profusely after such disturbances, according to the findings of Ky-Dembelé et al. (2007). The reverse "J" shape of cumulative diameter class distribution of all woody plants in each type of land tenure is an indicator of good regeneration status. Many individuals with a girth <5 cm dbh were found in each agroforestry parkland. The proportion of seedlings and saplings could therefore suffice to maintain a stable tree population.

However, the transition from seedlings to young saplings or higher size classes is a critical survival step of the recruitment stage where saplings are sensitive to frequent fire, browsing, drought, and livestock trampling, which induce seedling shoot die-back and compromise the successful transition from seedling to trees (Ky-Dembelé et al. 2007; Lankoandé et al. 2016). Thus, this transition often takes a long time, depending on many biotic and abiotic factors such as variation of rainfall, the availability of nutrients, the space and hydric stress, degeneration of young saplings, the substrate of seed germination, the anthropogenic pressures etc. (Scholes and Walker 1993; Eliapenda 2000; Kozlowski 2002; Sagar and Singh 2003). Also, factors such as grazing, fire, and labor influence biodiversity in agroforestry parkland by favoring preferred species and affecting tree size seriously.

4.3. Diversity of agroforestry parkland

Most diversity measures showed that the landowners' farms were most diverse than the non-landowners' farms. According to Shannon's and Simpson's diversity indices, woody populations in landowner's' farms were more diverse than non-landowner's' farms. This is most likely related to the relatively large numbers of abundant species found in the inventories plots at these farms (Tabuti and Mugula 2007). Shannon's diversity index is usually found to fall between 1.5 and 3.5 and is rarely above 5.0 (Magurran, 2004). The values found during inventories are in an acceptable range, i.e., ranged below 1.5 and 3.5. Simpson's index describes the evenness of the distribution of individuals among species at different types of land tenure as low. This is due to the difference in the importance value index (IVI) of the species on the type of land tenure (Tabuti and Mugula 2007) Analyses of variance of the entire woody vegetation of agroforestry parklands revealed no significant differences in terms of all computed indexes, basal area, or species richness. These findings corroborated with the results of (Augusseau et al. 2006), who found no major differences according to diversity indices such as Shannon index and Evenness index between native and migrant farmers' fields except for species richness. However, the obtained basal areas in this study are lower than those reported by De Wolf (1998), who found average basal areas up to 15 m^2/ha in the Soudano-Guinean climatic zone in Senegal. The high value of average basal areas may be due to high precipitation and denser tree vegetation than our study.

The average diameter and total basal area of trees ≥ 5 cm dbh were the largest in landowner's farms, which could be related to the land tenure effect where the landowners have no right to benefit from the advantages of trees in borrowed lands. Most indices showed that landowner's farms are more diverse than non-landowners farms. These findings may be explained by the fact in many cases, it is prohibited to non-landowners to plant trees in borrowed lands because planting is considered as an appropriation form of land.

4.4. Spatial distribution of seedling populations and similarity

Most seedling species have a clumped dispersion. This distribution pattern probably reflects the dominance of clonal propagation in the study area and is the survival strategy of woody plants after disturbances events (Sawadogo et al. 2002; Tabuti and Mugula 2007). The similarity in species composition between landowners' farms and non-landowners' farms was generally high, indicating the least diversity between both types of land

tenure. These similarities are probably due to the same site conditions. However, the reasons that motivated farmers to plant and conserve trees on farmland were linked to their utilities and rareness in the forest. This is consistent with the findings of Vodouhê et al. (2011), who found that people are more favorable to conserve in their fields the species that they perceive less available in the wild. In sub-Saharan Africa, trees are preserved on farmland because of the numerous benefits derived from them (food, commercialization of tree fruits, use of tree shade during farms activities and species contribution to soil fertility improvement, fuelwood, construction, medicine, climatic amelioration, and boundary markers (Lamien et al., 1996; Teklehaimanot 2004). Murniati et al. (2001) added that in the area where timber is the main product harvested from the forest (as the case of our context in Tiogo State Forest), farmers expressed a strong interest in growing high-quality timber in their mixed gardens to ensure a future timber supply. The factors such as lack of funds, lack of skill and silvicultural knowledge, land area, lack of germplasm, land and tree tenure that were found as factors influencing and conservation of trees on farms are consistent with previous studies (Buyinza and Ntakimanyire, 2008, Kabwe et al. 2009; Nyoka et al. 2011; Jamala et al. 2013; Mwase et al. 2015)

5. Conclusion

This study aimed to explore the species composition, structure, and diversity of woody species at agroforestry parklands according to land tenure. It reveals that the agroforestry parkland in Tiogo and the surrounding area has a large number of woody species, which is related to habitat heterogeneity and the real attention of farmers in the adoption of agroforestry systems. The results indicate that woody vegetation attributes decrease in landowners' farms. In each type of land tenure, the number of seedlings was disproportionately higher compared to adult trees, which could lead to higher recruitment of adults if measures are taken to improve the regeneration of woody species. Land tenure affected the biodiversity of agroforestry parkland. Land and tree tenure reforms may be the efficient solution to promote more active participation of non-landowner in agroforestry programs. Thus, when the local rights to use trees by non-landowners are flexible, they must be introduced and protected species in order to restore agricultural land and also diversify their productions. These findings highlight the important role of agroforestry parklands to maintain woody species richness and diversity and convert farmlands to biodiversity stock. The governments should pay more attention to development agencies, and ONGs should encourage the adoption of agroforestry practices by helping the local populations resolve the constraints that demotivate the improvement and promotion of agroforestry systems.

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